monthly departure curve should be raised sufficiently to eliminate the negative departures during January and February, a step which would be equivalent to assuming that the mean annual temperature at Madison is slightly increased by the presence of the lakes. This, however, can not be proved from the data at hand.

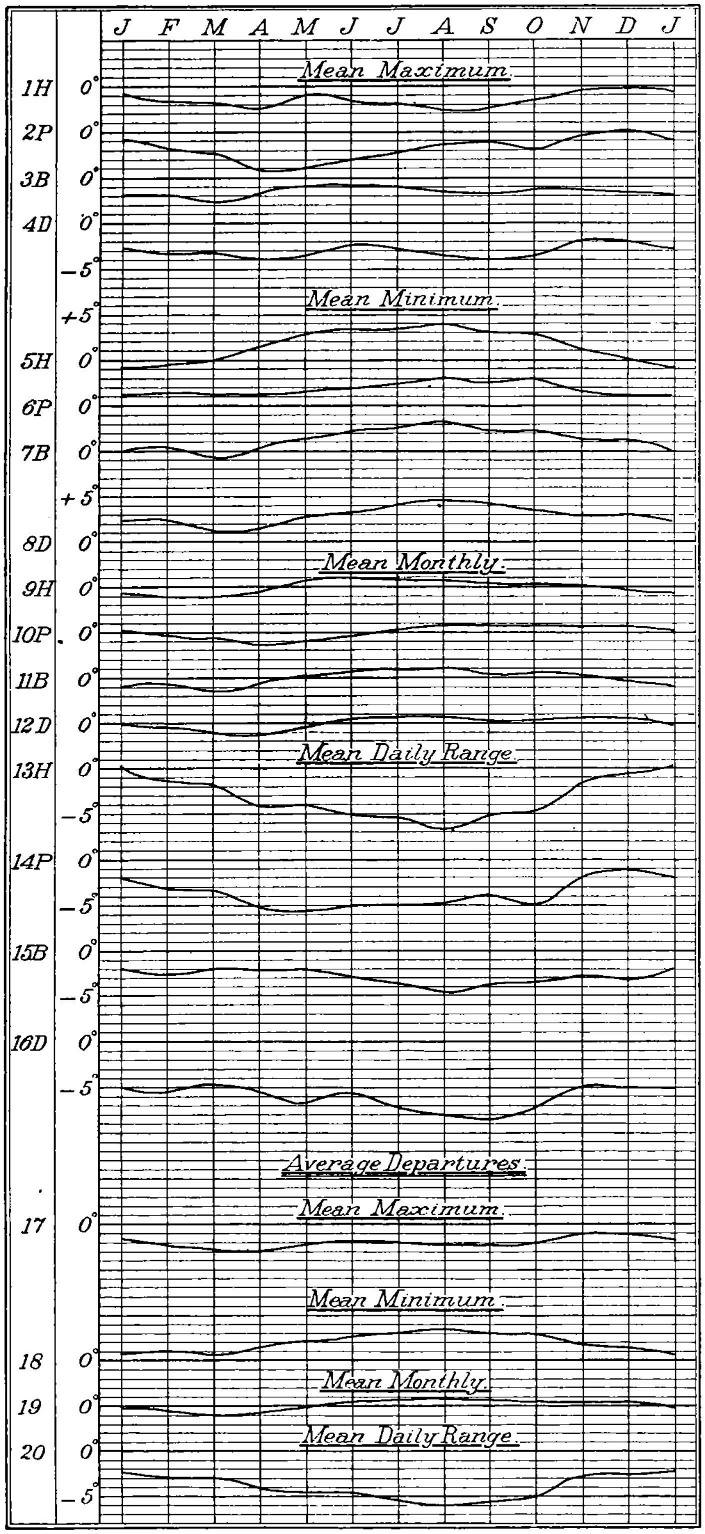

Fig. 1.—Departure curves.

In August the minimum curve reaches its extreme positive departure and the daily range of temperature averages six degrees less than that of neighboring purely continental exposures. Doubtless this is due to the presence of much water vapor in the air over the now well warmed lakes, this vapor absorbing much of the heat radiated from the sun during the day and from the earth at night. The high minimum during August indicates why the vicinities of small lakes during this month are less desirable pleasure resorts than at other seasons of the year.

The most marked tendency of the Madison temperature conditions to return to the purely continental type is shown in the curves from October to November, although the local lakes do not close until about December 21 as a rule. The freezing over of the lakes is usually preceded by several days of cold weather during which the temperature may fall nearly to zero. This cold spell frequently culminates on the day of closing and the succeeding few days are somewhat warmer. No decided change to the strictly continental type appears to occur near the date of closing, although a study of the Madison records for each year shows that the average decrease in temperature from the month preceding this date to the month following is about three degrees more than the normal.

While the exposure at Madison especially favors the influence of the lakes on the observed temperatures, yet it is believed that wherever small lakes are found, the temperature conditions in their vicinity will show departures from the purely continental type of their section much resembling those given above, though not so marked.

THE GREAT INDIAN EARTHQUAKE OF APRIL 4, 1905, AS RECORDED AT THE WEATHER BUREAU.

By Charles F. Marvin, Professor of Meteorology.

The great earthquake that almost entirely destroyed the mountain towns of Dharmsala, Kangra, and Palampier, in northwestern India, causing great loss of life and property over a wide extent of adjacent territory, was very fully recorded at Washington, D. C., on the Bosch-Omori seismograph at the Weather Bureau.

There is very little about the record to suggest that the disturbance was one of unusual character. In fact, we have records of other earthquakes apparently of decidedly greater violence, but whose foci appear to have been remote from populated regions. On this account or for some other reasons the disturbances were not marked by such great disaster and destruction as to draw widespread attention to their occurrence. Consequently our records in these cases have not been correlated with any published accounts of earthquakes.

In the case of the Indian earthquake, the vibratory motion as recorded at Washington persisted for an unusually long time (two hours and thirty minutes); but, on the other hand, that part of the record embracing the maximum displacement of the recording pen was relatively of short duration. It is reproduced in fig. 1.

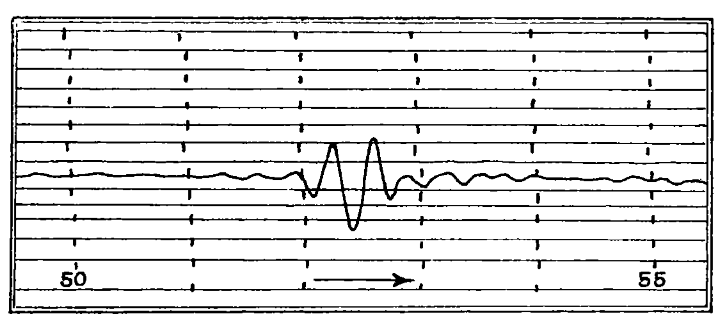

Fig. 1.—Maximum waves of Indian earthquake as recorded at Washington. Time correction +13 seconds.

The following table gives in detail the noticeable characteristics of the whole record.

Earthquake of April 4, 1905, seventy-fifth meridian time.

	h.	*m.*	*s.*
First preliminary tremors began	8	14	49 p. m.
Second preliminary tremors began	8	36	13 p. m.
Principal portion began	8	51	15 p. m.
Principal portion ended	8	54	13 p. m.
Maximum waves at	8	52	40 p. m.
End of earthquake	10	45	7 p. m.

Duration of first preliminary tremors		21 min.	24 sec.
Duration of second preliminary tremors		15 "	2 "
Duration of principal portion		2 "	58 "
Total duration of earthquake	2 hr.	30 "	18 "

Average complete period of small waves of principal portion	20 sec.
Average complete period of large waves of principal portion	15 "
Average complete period of small waves at end of principal portion	19 "

Period of pendulum	28 sec.
Maximum double amplitude of actual displacement of earth at seismograph	1.23 mm.
Magnification of record	10 times.

The north-south component of horizontal motion only was recorded.

The approximate location of the focus of this earthquake appears to have been somewhere near Dharmsala which seems to have suffered the greatest devastation. The geographic coordinates of Dharmsala are longitude 76° 23′ east; latitude 32° 16′ north. This point and Washington (longitude 77° 3′ west; latitude 38° 54′ north) may be located on a projection of the globe at D and W, respectively, as seen in fig. 2, where P is the north pole, and Dharmsala is considered to be located in the plane of the paper.

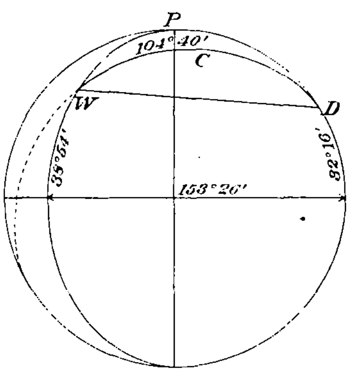

FIG. 2.

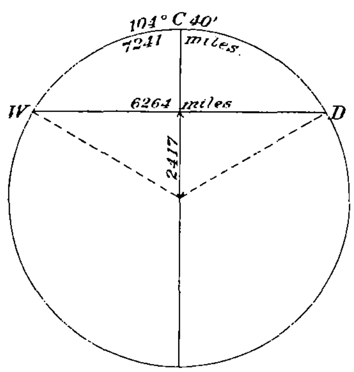

FIG. 3.

A brief consideration of some of the geophysical questions suggested by an examination of the data available indicates how imperfectly the structure and elastic properties of the earth are understood.

In fig. 2, $W\ C\ D$ represents the arc of the great circle through W and D; that is, the shortest distance between the two points measured on the surface of the earth. $W\ D$ likewise is the direct path from W to D through the interior of the earth. From trigonometry we find $W\ C\ D$ is an arc of 104° 40′; that is, a linear distance of 7241 statute miles. An earthquake traveling to Washington along this great circle would arrive from a direction 23° 40′ east of north.

Fig. 3 shows the relative positions of Washington and Dharmsala on the great circle of the earth, $W\ C\ D$, passing through them. The distance on the chord, W to D, is 6264 miles, and at the nearest point the line passes within 2417 miles of the center of the earth; that is, at a maximum depth below the surface of 1539 miles. In these computations the earth is regarded as a perfect sphere having a radius of 3956 miles, and the focus of the earthquake is assumed to lie within a few miles of the surface.

Data are not at present at hand giving the exact time of occurrence in India of any specified phases of the earthquake, but a report from Mussooree, located about 2° of longitude east of Dharmsala, states that the time of the severe shocks was 6:10 a. m., April 4, presumably local time. The corresponding local time at Dharmsala would be 6:02 a. m. The time of the first tremors at Washington, reduced to the Dharmsala meridian, would be about 6 hours 21 minutes a. m., making the time consumed in transmission about 19 minutes. If the waves were propagated along the surface of the earth and over the arc of a great circle, the speed of propagation from these figures must have been at nearly the rate of 6.4 miles (10.3 kilometers) per second; if propagated along the chord, the speed must have been nearly 5.5 miles (8.9 kilometers) per second.

The velocity of propagation of elastic waves in ordinary solid media is proportional to $\sqrt{\frac{E}{d}}$, where E is Young's modulus of elasticity, and d the density. It appears from the tables of the velocity of sound waves in different media that, owing to the high elasticity and small density of certain kinds of glass, elastic waves are propagated therein at a greater velocity than in any other known material, viz: 19,690 feet per second=3.7 miles per second.

From these considerations it appears that the calculated speed of propagation of the Dharmsala earthquake wave along the surface path is 73 per cent greater than the highest observed wave velocity in glass. Even if the waves followed the linear path through the interior of the earth the velocity of transmission would still be 49 per cent greater than the velocity in glass.

These statements relate to the propagation of the first earthquake tremors or small waves which travel at the highest velocities, and therefore reach distant points long before the great waves. The maximum waves traveled to Washington at a far slower rate, viz: 2.3 miles per second along the arc, and 2.0 miles per second along the chord.

The high speed waves are generally believed to be longitudinal waves, that is they consist of alternate compressions and expansions along the line of propagation analogous to the sound waves. If this be the case and the waves in the present earthquake traveled along the chord, then they should have seemed to emerge at Washington at a relatively high angle, i. e., 37° 40′ from the zenith. No measurement of this angle was actually made at Washington, but there is a mass of observational evidence to show that the vertical component of earthquake motion is so small that it has rarely been successfully measured, except near the origin, and then it is generally a small proportion of the horizontal motion. In the earthquake of April 4 the maximum north-south horizontal component of displacement at Washington was 1.23 mm. If the wave traveled on the chord, the corresponding component of vertical motion would have to be 1.74 mm. If a large component of this character existed it would be easy to measure it.

It seems very probable that earthquakes that are registered at great distances from their origin are propagated through very deep lying masses of the earth which appear to be highly elastic. The motions that are registered after coming out at the surface along the line of propagation are really secondary phenomena, representing effects set up in the relatively loose, nonhomogeneous surface layers by the deep-seated vibrations that are being propagated below.

Just what path is actually taken by the waves in cases of this sort is still an unsettled question among seismologists, and no generally satisfactory explanation of the high speed of propagation as related to the known elastic qualities of the earth has yet been given.